# 5.5 Geologic Hazards and Resources

This section discusses the potential geologic hazards and resources associated with the Amended Project. Specifically, the section discusses applicable LORS and existing conditions in the Project area; the Project's potential geologic hazards during Project construction and operation; potential geohazards and geologic resource impacts; and mitigation measures that eliminate or minimize these impacts.

This geologic assessment was based on a review of published geologic and mineral resource references, including the geotechnical investigation prepared for the original SSU6 AFC (Geotechnics, Inc., 2002). This information was supplemented with the results of a 2008 geotechnical investigation which provided a closer evaluation of subsurface conditions underlying major structures planned for the 160-acre site (Fugro, 2008). The 2008 geotechnical investigation is provided as Appendix B of the Amendment Petition. The results of the Fugro report were used by Tobey Wade Structural Engineers to develop specific recommendations with respect to foundation design and associated in-situ soil stabilization to be incorporated into the design and construction of the Amended Project (see Appendix B).

## 5.5.1 Summary of Differences between the Amended Project and Original SSU6

The Amended Project will result in no substantial changes to the affected environment and no significant changes in the Geological Hazards and Resources impacts compared to the original SSU6 project. As with the original project, seismic-related issues (e.g., ground shaking, liquefaction, and seiches) represent the main geologic hazards at the site. Slightly different specific areas are potentially affected because of changes in the footprint of the Amended Project compared to the original project (e.g., relocated production and injection well pads and pipelines).

The 2008 geotechnical investigations of the Amended Project plant site concludes that the underlying geologic features are generally consistent with those previously evaluated for the original SSU6 project (see Appendix B). As with the original project, geologic hazards and resource impacts during both construction and operation of the Amended Project would be less than significant after mitigation.

## 5.5.2 LORS Compliance

This section addresses the LORS applicable to geologic hazards and resources that are relevant to the Project. Table 5.5-1 summarizes the LORS that are expected to apply to the Amended Project. The Project will comply with applicable LORS during construction and operation.

**Table 5.5-1 LORS Applicable to Geological Resources and Hazards**

| LORS | Applicability | Where Discussed in AP |
|---|---|---|
| **Federal:** | | |
| None | No Federal LORS are applicable. | Not applicable |
| **State:** | | |
| California Public Resources Code (PRC) 25523(a): 20 California Code of Regulations (CCR) 1252 (b) and (c); Alquist-Priolo Earthquake Fault Zoning Act | Identifies areas subject to surface rupture from active faults. Prevents construction of buildings for human occupancy in these areas. None of the Amended Project components crosses an Alquist-Priolo Earthquake Zone. The Project will not be subject to requirements for construction within an Earthquake Fault Zone. | Sections 5.5.2 and 5.5.3 |
| California Public Resources Code, Division 3, Chapter 4, 3700-3776 | This code establishes requirements for drilling, constructing, and operating geothermal production and injection wells. | Section 5.5.2 |
| CCR, Title 14 Division 2,Subchapter 4; Statewide Geothermal Regulations Sections 1931-1932, 1937.1 | Sets forth rules and regulations governing the geothermal regulation program of the California Division of Oil, Gas, and Geothermal Resources (CDOGGR). Requires filing of a Notice of Intent (NOI) prior to drilling. This code establishes requirements for drilling, constructing, and operating geothermal production and injection wells in a manner to protect or minimize damage to the environment, usable ground waters (if any), surface water, geothermal resources, life, health, and property. | Section 5.5.2 |
| California Environmental Quality Act of 1970 (CEQA) | Appendix G, Section VI of the CEQA guidelines addresses geologic hazards and resources | Section 5.5.2 |
| **Local:** | | |
| Imperial County General Plan: Seismic/Geologic Hazards Elements | The Imperial County General Plan: Seismic/Geologic Hazards Elements provide an implementation program to reduce the threat of seismic and public safety hazards within unincorporated areas of Imperial County. | Section 5.5.4 |
| California Building Code (CBC), Chapters 16, 18, and 33 | Codes address excavation, grading, and earthwork construction, including construction applicable to earthquake safety and seismic activity. | Section 5.5.4 |

### 5.5.2.1 Federal LORS

There are no Federal LORS that apply directly to geologic hazards and resources or grading and erosion control.

### 5.5.2.2 State LORS

**California Public Resources Code 25523(a): 20 CCR § 1252 (b) and (c)**

The Alquist-Priolo Earthquake Fault Zoning Act (Alquist-Priolo Act) was passed in 1972 to prevent the construction of buildings used for human occupancy on the surface traces of active faults. None of the Amended Project components (plant site, injection well pads and pipelines) crosses an Alquist-Priolo Earthquake Zone. Thus, the Amended Project will not be subject to requirements for construction within an Earthquake Fault Zone.

**CCR, Title 14, Division 2, Subchapter 4, Statewide Geothermal Regulations § 1931-§1932; §1937.1**

This subchapter set forth the rules and regulations governing the geothermal regulation program of the CDOGGR as provided for by Chapter 4 (Sections 3700-3776), Division 3, of the Public Resources Code. This code establishes requirements for drilling, constructing, and operating geothermal production and injection wells in a manner to protect or minimize damage to the environment, usable ground waters (if any), surface water, geothermal resources, life, health, and property. The administering agency for the above regulation is the CDOGGR. The Amended Project will comply with the appropriate rules and reporting requirements of these regulations.

**California Public Resources Code, Division 3, Chapter 4, §3700-3776**

This code establishes requirements for drilling, constructing, and operating geothermal production and injection wells. This code sets standards for geothermal exploration and development that protect geothermal resources and prevent damage to underground and surface waters suitable for irrigation or domestic purposes from the drilling, operation, maintenance, and abandonment of geothermal wells. For the purpose of CEQA (commencing with Section 21000), this code establishes CDOGGR as the lead agency; however, under PRC Section 3715.5, CDOGGR may delegate its authority to a county. Currently, Imperial County is the only county that has been delegated this authority by CDOGGR. The permit and reporting requirements set forth in this code are consistent with those described in CCR, Title 14, Division 2, Subchapter 4, Statewide Geothermal Regulations §§ 1931-1932 and § 1937.1. The administering agency for the above regulation is Imperial County. The Project will comply with the appropriate rules and reporting requirements of this regulation.

**California Building Code (CBC)**

The 2007 edition of the CBC is based on the Uniform Building Code (UBC) with revisions specifically tailored to geologic hazards in California. The UBC specifies acceptable design criteria for structures with respect to seismic design and load bearing capacity and the State has adopted these provisions in the CBC. The Project is subject to the applicable sections of the CBC. Imperial County is responsible for implementing the CBC for the Project.

**CBC Chapter 16: Structural Design Requirements, Division IV Earthquake Design**

This section requires structural designs to be based on geologic information for seismic parameters, soil characteristics, and site geology.

**CBC Chapter 18: Foundations and Retaining Walls, Division I**

This section sets requirements for excavations and fills, foundations, and retaining structures, with regard to expansive soils, subgrade bearing capacity, and seismic parameters. In addition, it addresses waterproofing and dam-proofing foundations. In Site Class D and E as defined by the CBC, liquefaction potential at the site should be evaluated. Division III contains requirements for mitigating effects of expansive soils for slab-on-grade foundations.

**CBC Chapter 33: Site Work, Demolition and Construction, and Appendix Chapter 33**

These sections establish rules and regulations for construction of cut and fill slopes, fill placement for structural support, and slope setbacks for foundations.

### 5.5.2.3 Local LORS

The Project is subject to Imperial County's requirements for building and grading permits.

**Seismic/Geologic Hazards Element of the Imperial County General Plan**

The Imperial County General Plan's Seismic/Geohazards Element provides an implementation program to reduce the threat of seismic and public safety hazards within unincorporated areas the County.

### 5.5.2.4 Involved Agencies

Agencies with jurisdiction to enforce LORS related to geologic hazards and resources, and contacts at those agencies are summarized in Table 5.5-2. Imperial County traditionally works jointly with the CDOGGR to regulate and develop the geothermal resources in the Imperial Valley.

**Table 5.5-2 Agencies and Agency Contacts**

| Agency/Contact | Phone/Email | Permit/Issue |
|---|---|---|
| Mike Woods<br>Geothermal Engineer<br>CDOGGR<br>605 Wake Avenue<br>El Centro, CA 92243 | (760) 353-9900<br>mwoods@consrv@ca.gov | Requirements for drilling, constructing, and operating geothermal production and injection wells |
| Jurg Heuberger, Director<br>Imperial County Planning & Development Services Dept.<br>801 Main Street<br>El Centro, CA 92243 | 760) 482-4310<br>jurgheuberger@imperialcounty.net | Grading Permit<br>Building Permit |

### 5.5.2.5 Required Permits and Permit Schedule

Required permits are summarized in Table 5.5-3. CDOGGR permits production and injection well drilling.

**Table 5.5-3 Required Permits**

| Permit | Agency | Schedule |
|---|---|---|
| NOI to Drill (Production and Injection Wells) | CDOGGR | Prior to construction |
| Building and Grading Permits | Imperial County Planning Department | Prior to construction |

## 5.5.3 Affected Environment

This section discusses the existing geologic environment including the underlying geologic structures, seismicity, and geologic hazards of the Amended Project site (plant site, injection well pads and pipelines). Much of the discussion is drawn from the original SSU6 AFC, supplemented by additional research to update the earlier material and ensure appropriate coverage of the specifics of the Amended Project. The Project is in the Imperial Valley along the southeast end of the Salton Sea. Elevations at the plant site range from approximately 230 feet below mean sea level (msl) at the lowest point along the west side to approximately 220 feet below msl along the east side of the site, for an average elevation of approximately 225 feet below msl. Juxtaposed against the generally flat terrain is Obsidian Butte, which lies approximately 0.5 miles west of the site. This volcanic glass dome rises approximately 100 feet above the surrounding farmland.

The injection well pipelines traverse flat farmland topography similar to the plant site. The major difference is the presence of irrigation canals and/or drains that parallel or cross the alignments. In general, these features consist of near vertical-walled trenches ranging from 5 to 10 feet deep and 10 to 30 feet wide.

### 5.5.3.1 Regional Geology

The site is located in a south-central portion of the Salton Trough, a topographic and structural depression within the Colorado Desert geomorphic province. This area is shown in Figure 5.5-1. Geologic features in the Project vicinity are shown on Figures 5.5-2.

The Colorado Desert geomorphic province is a low-lying barren desert basin between active branches of alluvium-covered San Andreas Fault with the southern extension of the Mojave Desert province in the east. It is bounded to the east by the Chocolate Mountains, to the west by the Peninsular Ranges and extends south into Mexico. This province includes a large portion of Imperial County and a small portion of central Riverside County. The Colorado Desert is divided into two main valleys, the deep Imperial Valley to the south and the narrower and shallower Coachella Valley to the north. A significant portion of both valleys lies below msl with the lowest elevation found in the Salton Basin at 235 feet below msl. The area is characterized by the ancient beach lines and silt deposits of extinct Lake Cahuilla (CGS, 2002a).

The three main fault zones that comprise the San Andreas Fault system in this region form clear tectonic boundaries around the Salton Trough. Geophysical studies indicate the presence of a steep gravity gradient across the San Andreas Fault along the eastern edge of the Trough (Biehler, et al., 1964). The Orocopia and Chocolate Mountains represent the broken edges of the plate along the eastern margin of the Salton Trough and are included in the southern Basin and Range physiographic province (Frost, et al., 1997). The eastern edge of the Pacific plate is composed of intermediate composition granitic rocks of the Peninsular Ranges physiographic province. This eastern edge of the plate, which forms the western portion of the Salton Trough, has been offset along multiple strands of the San Andreas system, including the

Elsinore and San Jacinto faults. The Salton Trough occupies the structurally weak zone between the strong, solid edges of the Pacific and North American plates. A zone of high seismicity connects the San Andreas Fault north of the Salton Sea and the Imperial Fault south of the City of Brawley. The structurally low area is referred to as the Brawley Seismic Zone, and it may be the result of a tensional or releasing step between the San Andreas and Imperial faults.

### 5.5.3.2 Seismicity

The Project site and its linear facilities are located in one of the most seismically active portions of California. The region has experienced numerous earthquakes in the past. The majority of the relative motion between the North American and Pacific plates in California occurs in the San Andreas Fault system (Hutton, et al., 1991; Sieh and Jahns, 1984). The location of the Project facilities in relation to faults in the region is shown in Figure 5.5-2. No known active faults have been identified at the Project site.

An “active” fault is defined as a fault that has experienced seismic activity during historical times (since roughly 1800) or exhibits evidence of surface displacement during the Holocene Epoch (approximately 9600 BC to present). Table 5.5-4 presents a list of significant faults within a 50-mile radius of the Project site. Other currently unknown active faults without surface expression (blind faults) that are capable of generating seismic activity may also be present.

A search of the known sufficiently active faults within a 50-mile radius of the subject property was conducted using the EQFAULT computer program (version 3.0) (Blake, 2000). EQFAULT provides the approximate distance from a site to known active faults, the estimated maximum earthquake potential for a given fault, and the estimated peak site ground acceleration relative to the force of gravity (g). Table 5.5-4 shows the applicable data for the Project site. Key faults shown in Table 5.5-4 are discussed in text following the table.

**Table 5.5-4 Faults in the Project Region**

| Fault Name | Approximate Distance From Plant Site (miles) | Estimated Maximum Earthquake Magnitude | Estimated Peak Site Acceleration (g) |
|---|---|---|---|
| Elmore Ranch | 10 | 6.6 | 0.401 |
| San Andreas – Southern | 13.5 | 7.4 | 0.285 |
| San Andreas – Coachella | 13.5 | 7.1 | 0.238 |
| Superstition Hills (San Jacinto) | 15.7 | 6.6 | 0.143 |
| Imperial | 16.5 | 7.0 | 0.167 |
| San Jacinto – Borrego | 16 | 6.6 | 0.093 |
| Superstition Mtn. (San Jacinto) | 18.8 | 6.6 | 0.116 |
| San Jacinto – Anza | 20 | 7.2 | 0.113 |
| San Jacinto – Coyote Creek | 32.5 | 6.8 | 0.070 |
| Laguna Salada | 36 | 7.0 | 0.079 |
| Elsinore – Coyote Mountain | 35 | 6.8 | 0.065 |
| Elsinore – Julian | 44.4 | 7.1 | 0.061 |

**Table 5.5-4 Faults in the Project Region**

| Fault Name | Approximate Distance From Plant Site (miles) | Estimated Maximum Earthquake Magnitude | Estimated Peak Site Acceleration (g) |
|---|---|---|---|
| Earthquake Valley | 45.4 | 6.5 | 0.035 |
| (Generated and modified from Blake, 2000). | | | |

**Brawley Seismic Zone**

The proposed plant site, well pads, and linear facilities are located within the Brawley Seismic Zone. This structural depression lies between the San Andreas Fault to the northeast and the Imperial Fault to the southwest. The Brawley Seismic Zone was first recognized because of the number of earthquake swarms produced from 1973 through 1979 (Johnson and Hutton, 1982). Analysis of these swarms suggests they are triggered by creep events on the Imperial Fault (Johnson, 1982). The blind faulting controlling the geothermal resource geometry does not extend into recent sediments and, therefore, is not considered a potential source of ground rupture. The Brawley Seismic Zone is characterized by earthquake swarms, generally less than magnitude 3 or 4. California Division of Mines and Geology (CDMG) fault parameters for the Brawley Seismic Zone indicate a slip rate of one inch per year and a maximum moment magnitude of 6.4. The estimated maximum earthquake magnitude is 6.4 and estimated peak acceleration is 0.459g (Blake, 2000).

**Elmore Ranch Fault Zone**

The Elmore Ranch fault zone is approximately 10 miles west of the plant site. The fault zone is composed of six northeast-southwest trending parallel segments up to 7.5 miles long. These are commonly termed the Elmore Ranch Fault, the West Elmore Ranch Fault, the East Elmore Ranch Fault, and the Lone Tree Fault. The 1987 magnitude 6.2 Elmore Ranch Earthquake ruptured these faults and triggered slip on the Superstition Hills Fault, which followed with a magnitude 6.6 event approximately 12 hours later. The surface rupture reported on the Elmore Ranch Fault was 7.2 miles (California Geological Survey, 2002). Aftershocks of the Elmore Ranch Earthquake extended into the Brawley Seismic Zone to the east (Magistrale, et al., 1989). CDMG fault parameters for the Elmore Ranch Faults indicate a combined slip rate of 0.04 inches per year and a maximum moment magnitude of 6.6.

**San Andreas Fault Zone**

The Coachella Valley segment of the San Andreas Fault is approximately 59 miles long and extends from the town of Indio to Bombay Beach on the northeast shore of the Salton Sea, approximately 14 miles from the plant site. North of Indio, the fault splays into two active strands, the Banning and the Mission Creek faults. The San Andreas Fault has not been mapped south of the Salton Sea. While a linear extension of the fault may exist under the Salton Sea or in the northern Imperial Valley, there has been no geologic or geophysical evidence to support it (Sharp, 1982). Most of the aftershocks following the 1979 earthquake on the Imperial fault occurred within the Brawley Seismic Zone (Sharp, 1982). The Imperial Fault has a similar strike as the southern segment of the San Andreas Fault and has been modeled as a releasing step with the Brawley Seismic Zone occupying the resulting structural depression (Frost, et al., 1997). This locked, southernmost section of the Fault also lacks microseismicity and stands in sharp contrast to the northern sections of the Fault that have ruptured with the largest historical earthquakes in California. CDMG fault parameters for the Coachella segment of the San Andreas Fault indicate a slip rate of one inch per year and a maximum moment magnitude of 7.1.

**San Jacinto Fault Zone**

The San Jacinto Fault Zone is approximately 16 miles west of the plant site. This zone is a major tectonic and seismic structure, striking northwest for more than 124 miles. The San Jacinto fault zone is part of the San Andreas Fault system. The southern segment of the San Jacinto Fault Zone is composed of the Coyote Creek Fault, the Superstition Hills Fault, and the Superstition Mountain Fault. The Coyote Creek strand of the Fault Zone extends from just north of Borrego Springs to the northeast end of the Fish Creek Mountains, north of Plaster City. The most recent large earthquakes to occur on the San Jacinto Fault system were the magnitude 6.4 Arroyo Salada Earthquake of 1954, the Borrego Mountain earthquake (magnitude 6.6) in 1968, and the Superstition Hills earthquake (magnitude 6.6) in 1987. CDMG fault parameters for the San Jacinto Fault Zone are given for each segment as follows: Coyote Creek - 0.16 inches per year slip rate and maximum moment magnitude of 6.8; Superstition Hills - 0.16 inches per year slip rate and maximum moment magnitude of 6.6; and Superstition Mountain - 0.2 inches per year slip rate and maximum moment magnitude of 6.6.

**Imperial/Brawley Fault**

The Imperial Fault Zone is approximately 16.5 miles southeast of the plant site. This northwest trending fault is approximately 40 miles long and extends southeastward from an area just southwest of the City of Brawley to the town of Saltillo, Mexico. The Brawley Fault is the northeastern branch of the Imperial Fault and was generally unrecognized until a series of small earthquakes causing surface rupture occurred in 1975 (Sharp, 1972). Both faults ruptured together in the 1979 magnitude 6.4 event, confirming its presence and relationship to the Imperial Fault (Johnson and Hutton, 1982). The 1979 earthquake produced seismic intensities at Niland and Calipatria of V to VI (Reagor, et al., 1982). CDMG fault parameters for the Imperial Fault indicate a slip rate of 0.8 inches per year and a maximum moment magnitude of 7.0.

**Elsinore Fault Zone**

The Elsinore Fault Zone is approximately 35 miles west of the plant site. The southern segment of the Elsinore Fault is approximately 124 miles long and extends from the Los Angeles Basin, where it splays into the Whittier and Chino faults, to the southwest end of the Imperial Valley, west of El Centro. This fault zone is the major structural boundary between the Peninsular Ranges and the west side of the Salton Trough (Frost, et al., 1997). The Elsinore Fault Zone is characterized by a moderate amount of seismicity, having experienced several earthquakes in the magnitude range magnitude 5.0 to 6.0. The only large earthquake to occur on the Elsinore Fault in the historic record is the magnitude 6.0 earthquake along the central section in 1910. CDMG fault parameters for the Elsinore Fault indicate a slip rate of 0.16 inches per year and a maximum moment magnitude of 6.8.

**Laguna Salada Fault**

The Laguna Salada Fault trends northwest and is approximately 36 miles southwest of the plant site in northern Baja California, Mexico. The Fault is approximately 47 miles long and forms a boundary along the western margin of the Sierra Cucapa Mountains. The most recent large earthquake along the Laguna

Salada Fault is most likely an earthquake in 1892. The estimated moment magnitude for this event, based on ground rupture lengths and measured offsets is 7.1 (Mueller and Rockwell, 1995). CDMG fault parameters for the Laguna Salada Fault indicate a slip rate of 0.14 inches per year and a maximum moment magnitude of 7.0.

### 5.5.3.3 Geologic Hazards in the Vicinity of the Project Site

This section describes the geologic hazards in the vicinity of the Project site.

**Seismic Ground Shaking and Ground Rupture**

The Amended Project site is located in a seismically active area; thus, there is a potential that Project structures may experience one or more moderate-to-severe ground shaking events during the facility's operating life. Based on available online Seismic Hazard Zone maps by the California Geological Survey (2007), the plant and linear facilities are in areas that have not been mapped for seismic hazards. Based on the California Geological Survey's (2003) Probabilistic Seismic Hazards mapping Ground Motion Page, there is a 10 percent probability of earthquake ground motion exceeding 0.45g at the plant site over a 50-year period. Regarding the linear facilities, there is a 10 percent probability of earthquake ground motion exceeding 0.37 to 0.47g over a 50-year period.

A probabilistic seismic analysis was performed for the original SSU6 AFC to provide an estimate of the potential peak ground acceleration (PGA) that plant site structures may experience. The probabilistic analysis incorporated the contribution of all known active faults within a 62-mile radius of the site for which published data was available. The goal of the analysis is to account for uncertainty in rupture size, rupture location, magnitude and frequency, as well as uncertainty in the attenuation relationship. Based on the results of the probabilistic analysis, the Upper Bound Earthquake for the site results are a PGA of 1.35g and an associated return period of roughly 1,000 years. The Upper Bound Earthquake is defined as the motion having a 10 percent probability of being exceeded in 100 years. The Design Basis Earthquake is estimated to have a 10 percent probability of being exceeded in 50 years (or a 475-year return period). The Design Basis Earthquake results in a PGA of 1.16g.

As discussed previously, the plant site, well pads and pipelines are located within the Brawley Seismic Zone. This zone is defined by epicenters of microseismic events or aftershocks, following earthquakes on adjacent active faults rather than from geologic mapping of surface ruptures and geomorphic features. Although stress is being transferred to the Brawley Seismic Zone from adjacent active faults, historic and microseismic records indicate the stress is released gradually through relatively constant earthquake swarm activity. This results in a fault-creep type mode of deformation with characteristic earthquakes generally less than magnitude 3.0. Therefore, the potential for ground rupture at the site is considered to be low. It should be noted that while ground rupture would most likely occur along previously established fault traces, future ruptures could occur at other locations.

**Liquefaction**

Liquefaction is a phenomenon that may occur because of ground shaking at locations where cohesionless soils are present and groundwater levels are shallow. It is a soil condition in which seismically induced ground motion causes an increase in soil water pressure in saturated, loose, sandy soils, resulting in loss of soil shear strength. Liquefaction can lead to near-surface ground failure, which may result in loss of foundation support and/or differential ground settlement. Sandy deposits deeper than 50 feet below ground surface are usually not prone to causing surface damage. In addition, soils above the groundwater table (soils that are not saturated) will not liquefy.

The site is within the Imperial Valley, an area that is susceptible to liquefaction. The 1940 and 1979 earthquakes on the Imperial Fault caused widespread liquefaction in areas underlain by alluvium, areas adjacent to canals and drains, and in areas underlain by lake deposits. These liquefiable sites contained predominantly loose sandy soils, or sequences of thick sandy layers within finer grained soils (Youd and Wieczorck, 1982).

A liquefaction analysis was performed on data from cone penetrometer tool (CPT) soundings conducted at the site during the original SSU6 geotechnical investigation. Results of the analysis indicated that liquefaction of some of the sandy deposits is likely even with relatively low levels of ground shaking from one of the many nearby seismic sources (as low as 0.2 to 0.3g). The magnitude-weighted Design Basis PGA from the probabilistic analysis is 0.92g. At this level of ground shaking, much of the sandy deposits at the site will likely liquefy. The injection pipelines and well pads are similarly affected by liquefaction because they are underlain by the same or similar geologic and groundwater conditions. The 2008 geotechnical investigation came to similar conclusions with respect to liquefaction potential. Thus, due to the relatively shallow groundwater levels in the vicinity of the plant site, well pads and pipelines, the potential for liquefaction is considered high.

**Slope Instability**

The Project site consists of generally flat terrain that is not prone to significant mass wasting or slope stability problems.

**Subsidence**

The Project site is subjected to subsidence from regional tectonic processes and from localized fluid withdrawal. Subsidence data compiled by the Applicant from their local survey network indicates approximately 0.8 inches to 2.4 inches of settlement in the general vicinity proximate to CE Generation's operating plants and production and injection well fields from 1989 to 1999. These values most likely represent localized subsidence because of fluid withdrawal resulting from geothermal production. Due to the depth of the reservoir, the amount of subsidence caused by fluid withdrawal at the site does not create significant differential settlement conditions. Consequently, the potential for damaging localized differential settlement from fluid withdrawal subsidence is considered low.

The site is within a region of active subsidence because of regional faulting. The Salton Trough is filled with up to 20,000 feet of Cenozoic-age sediments. Regional subsidence resulting from a combination of tectonic processes, including faulting and possible reservoir loading by the Salton Sea, may combine to produce roughly 1.6 inches of settlement per year across the entire Salton Trough (Lofgren, 1978). Subsidence resulting from tectonic processes generally occurs over large areas. Consequently, the potential for damaging localized differential settlement from regional subsidence is considered low.

As discussed in the previous section, the site is potentially liquefiable. Liquefaction is commonly followed by settlement as the excess pore pressures dissipate and the sand grains redistribute stresses. Post-liquefaction settlement at the site was estimated in the geotechnical investigation performed for the original

SSU6 project based on CPT soundings. Results of this analysis indicate that post-liquefaction settlement at the site may vary from 6 to 9 inches. Findings of the 2008 geotechnical investigation are consistent with the earlier study. Total differential settlement across the site from complete liquefaction may typically be on the order of 3 to 4 inches. Differential settlement across small structures may be less than this amount.

The soft, loose, surficial soils that exist at the site are compressible and not suitable for the direct support of fill or foundation loads. The amount of settlement may vary based on the magnitude of the foundation loads (Geotechnics, Inc., 2002).

**Expansive Soils**

Expansive soils consist of fine-grained clay, which is subject to swelling and shrinkage, varying in proportion to the amount of moisture present in the soil. Shallow soils at the site are composed of saturated lean clay. These surficial soils are between 2 and 6 feet thick and laboratory testing indicates they have a medium expansion potential (Geotechnics, Inc., 2002).

**Erosion**

Erosion is the displacement of solids (soil, mud, rock, and other particles) by wind, water, or ice and by downward or down-slope movement in response to gravity. Due to the generally flat terrain of the plant site, it is not considered prone to significant mass wasting due to gravity. However, soil characteristics at the plant site and associated facilities allow for the potential for wind and water erosion. For more details on potential wind and water erosion associated with the Project and mitigation measures that will be implemented to reduce any potentially significant erosion impacts to less than significant levels, see Section 5.12, Soils.

**Seiches**

A wave created by earthquake shaking in an enclosed body of water is called a seiche. The potential for a seiche to occur is related to the natural frequency of vibration of the body of water, as well as the predominate frequencies of vibration in the seismic event. The possibility may exist for a seiche to occur in the Salton Sea. Seiches have not been recorded during recent earthquakes in the Imperial Valley. However, because the site is situated below the level of the Salton Sea, and because the Vail Lateral 5 Drain embankment along the western side of the site has only a few feet of freeboard, the potential for flooding at the site as a result of a seiche is considered moderate. The linear facilities and well pads nearest to the generator may be subject to similar flood hazard.

**Volcanic Eruptions**

Volcanic eruptions cannot be prevented or stopped, but certain actions can be taken to reduce the risk of loss of life and damage. Most volcanic eruptions involve the rise of magma toward the surface. This upward movement of magma normally generates detectable characteristic earthquakes, deformation of the ground surface, and changes in heat flow and chemistry of the surrounding groundwater. The site is currently monitored with seismometers, which would detect magma-generated earthquakes. Surface deformation associated with rising magma at the site would be detected by the subsidence monitoring network currently in place. Finally, changes in reservoir temperature and chemistry would be noticed during standard production well monitoring during plant operation. This existing monitoring system will provide adequate warning to evacuate personnel and safely shut down the generating plant. Therefore, volcanic eruption is not considered a significant hazard to public safety at the site.

**Tsunamis**

The site, well pads, and linear facilities are situated several hundred feet below msl. This suggests that the potential may exist for inundation in case of a tsunami (seismic sea wave) within the Gulf of California. However, the distance of the site from the Gulf (120 miles) and the higher ground surface elevations to the south of the site associated with the Colorado River delta, provide some measure of protection from such events, as there are no records (historic or geologic), which indicate that tsunamis have impacted the Imperial Valley in the last several hundred years. Therefore, the potential for flooding at the Project site as a result of a tsunami is considered low.

### 5.5.3.4 Geologic Resources

Mineral resources in the vicinity of the Project site are depicted on Figure 5.5-3. Minor aggregate (pumice) or mineral mining operations have been documented within two miles of the site in the volcanic outcrops at Obsidian Butte and Rock Hill. These are small deposits of volcanic breccia that are no longer mined. There are no known hydrocarbon resources within two miles of the site (California Department of Conservation, 1977).

The Project lies within a known geothermal resource area, within the Salton Sea Geothermal Field where the brines contain unusually high concentrations of metals including zinc, lead, copper, silver, iron, manganese, sodium, calcium, potassium, and lithium. Sediments in the deeper parts of the field contain widespread ore minerals including pyrite, hematite, sphalerite, chalcopyrite, marcasite, and galena. These minerals likely originate from diagenetic, replacement, and vein filling/pore filling mineralization processes.

Carbon dioxide ($CO_2$) gas was produced north of the site, from 1933 to 1954 from shallow sands 200 to 700 feet deep. The $CO_2$ recovered from these shallow wells was used to produce dry ice (Elders, 1979).

The Project is adjacent to Obsidian Butte, one of the small volcanic glass domes that comprise the Salton Buttes. Obsidian Butte is a popular stop for geologic field trips due to the unique composition (low potassium tholeitic basalt identical in composition to oceanic crust rocks) and location (at the surface on the continental margin). The Project does not represent a significant impact to this geologic resource because the Project will not impact its accessibility.

**Geothermal Resources**

In the Project vicinity, the deeper geothermal field reservoir fluids have total dissolved solids (TDS) values that range from 17 to 27 weight-percent (wt-%). These TDS concentrations are consistent with the 19 to 26-wt-% range found in reservoir fluids extracted from geothermal production wells. The TDS of the reservoir fluids generally increase as a function of both increasing depth within the system and movement laterally to the northeast. Reservoir fluids have non-condensable gas (NCG) contents that range from 0.1 to 0.8 wt-%. The principal constituent of the NCG is $CO_2$. Expected properties of the produced fluid are as follows:

- 250,000 mg/l TDS
- 0.3 percent NCG (at high pressure separation pressure)

- Total enthalpy: 400 Btu/lb
- Equivalent Reservoir Temperature: 535ºF

For further discussion on the geothermal resource (e.g. the anticipated chemical composition of the produced fluids), refer to Section 2.0, Project Description.

## 5.5.4 Environmental Impacts

Potential impacts from the proposed Project on the geologic or mineral resources and potential impacts of geologic hazards on the Project are divided into those related to construction activities and those related to plant operation.

Significance criteria were developed based on CEQA Guidelines. The significance criteria used in evaluating potential geologic-related impacts are shown below. Impacts would be considered significant if:

- Surface rupture occurred as a result of faulting or due to mass movements or settlement from seismic shaking;
- Liquefaction occurred as a result of shallow groundwater and seismic shaking;
- Subsidence occurred as a result of existing soil conditions or seismic shaking;
- Mass wasting occurred as a result of land sliding and soil creep; and/or
- Construction of the Project interfered with access to mineral resources.

### 5.5.4.1 Construction

Amended Project construction-related impacts to the geologic environment or mineral resources are primarily related to terrain modification (cuts, fills, or drainage diversion measures), drilling of production and injection wells, and ground improvement for foundation support. The proposed improvements also include the excavation of three brine ponds, six mud sumps and a borrow area.

The Amended Project will be designed and constructed to meet CBC requirements for industrial facilities located in Site Class D or E. The Project will adhere to sound professional practices and comply with regulatory requirements related to geologic hazards such as grading and slope stability. With implementation of planned mitigation measures, Project geological hazards impacts will be less than significant.

Because of the shallow groundwater, slope stability is of concern during construction. Temporary construction slopes should be stable provided that the excavations are dewatered and/or do not extend to depths where heavy seepage is encountered. Shallow failures on the sidewalls of the detention basin may be possible given sufficient long-term seepage. Typical cut-and-fill depths of less than two to three feet are anticipated for these minor grading improvements; cut and fill at the borrow area near the plant site will be to a depth of four to five feet. As the borrow site will be returned to pre-existing conditions, no significant impacts would occur from excavation. Drilling operations for the production and injection wells may require minor grading to provide a level pad during development. Ground improvement operations to mitigate the site for settlement-sensitive improvements are expected to be limited to within 50 feet of the ground surface.

Site development is not anticipated to result in significant adverse impacts to geologic or mineral resources. Potential impacts of geologic conditions on construction of the Project include shallow groundwater conditions and soft soils.

In addition to pile driving for foundations beneath heavy equipment in the power block areas in order to minimize liquefaction, soil treatment is planned to improve the onsite soil under the laydown area, well pads, roads, and the power block areas. With implementation of the mitigation measures outlined in Section 5.5.6, geological hazards to the construction of the Amended Project will be reduced to less than significant levels.

#### 5.5.4.2 Operations

Regional and local geologic conditions will not be altered significantly by the long-term operation of the Project. No major unique geologic or physical features have been identified at the plant site, along the linear facility routes or in the areas designated for mining of structural fill (e.g. the borrow areas).

Improper management associated with the extraction of geothermal fluids has been known to cause regional subsidence proximate to other geothermal projects. The Applicant's on-going operations, as well as the Amended Project, incorporate carefully planned and executed re-injection of geothermal fluids. The success of this program is constantly evaluated by the Applicant through monitoring of reservoir geophysical data and surface subsidence proximate to the existing operating plants and well field. After over two decades of operation, this monitoring indicates very minor impacts to the geothermal resource and no significant surface subsidence. As the Applicant intends to extend the resource management and monitoring programs to encompass the Amended Project, it is expected that depletion of the geothermal reservoir and surface subsidence impacts will be less than significant.

#### 5.5.4.3 Cumulative Impacts

Cumulative impacts of the Amended Project on geologic hazards and resources of geothermal development can stem from the extraction of geothermal fluids. As noted above, improper management of fluids extraction could lead to regional subsidence and/or a decline in the long-term viability of the geothermal resource. The Applicant's ongoing operations in the KGRA, as well as the Amended Project, include carefully planned reinjection of geothermal fluids. The brine reinjection program monitors reservoir geophysical data and surface subsidence on an ongoing basis at the nine existing operating plants and well fields within two miles of the Amended Project site. The monitoring indicates no significant surface subsidence and only very minor effects to the geothermal resource. The Applicant will incorporate the Amended Project into the ongoing program to manage and monitor fluids extraction and reinjection. As is the case for the Amended Project, other geothermal projects also would be required to comply with the seismic and subsidence monitoring requirements of the Imperial County General Plan Geothermal Element. Cumulative effects of the Amended Project on geologic hazards and on the geothermal resource would be less than significant.

### 5.5.5 Mitigation Measures

Geologic hazards and resources mitigation measures are embodied in the CEC's Conditions of Certification (COC) for the original project. Applicant –proposed modifications to these COCs are shown in the following section.

## 5.5.6 Conditions of Certification

The Commission Final Decision for the SSU6 project included Condition of Certification (COC) GEO-1. A number of additional COCs applicable to geologic hazards were included in the Facility Design section of the Final Decision (GEN-1, GEN-5, and CIVIL-1). These various COCs are provided below. Applicant-recommended deletions from the existing Condition language are shown with strikethrough; new or revised wording is shown in italics. The only changes recommended are to change the California Building Code (CBC) references in various COCs to reflect the 2007 CBC update.

**GEO-1** The project owner shall comply with the seismic and subsidence monitoring standards set forth in the Imperial County General Plan, Geothermal and Transmission Element.

**Verification:** At least 30 days prior to the start of construction, the Project Owner shall submit a seismic and subsidence monitoring plan to the Imperial County Public Works Department for review and approval. The Project Owner shall submit a letter to the (Compliance Project manager (CPM) showing evidence of review by the Imperial County Public Works Department that the plan meets the above referenced requirements. In addition, after start of commercial operation the Project Owner shall submit to the County an annual report outlining the seismic and subsidence monitoring performed during the previous year as required by the above referenced requirements. Evidence that the report has been accepted as adequate by the County shall be provided to the CPM annually.

**GEN-1** The project owner shall design, construct and inspect the project in accordance with the ~~2001~~ *2007* California Building Standards Code (CBSC) (also known as Title 24, California Code of Regulations), which encompasses the CBC, California Building Standards Administrative Code, California Electrical Code, California Mechanical Code, California Plumbing Code, California Energy Code, California Fire Code, California Code for Building Conservation, California Reference Standards Code, and all other applicable engineering LORS in effect at the time initial design plans are submitted to the CBO for review and approval. (The CBSC in effect is that edition that has been adopted by the California Building Standards Commission and published at least 180 days previously.)

All transmission facilities (lines, switchyards, switching stations and substations) are handled in Conditions of Certification in the Transmission System Engineering section of this document.

In the event that the initial engineering designs are submitted to the CBO when a successor to the ~~2001~~ *2007* CBSC is in effect, the ~~2001~~ *2007* CBSC provisions identified herein shall be replaced with the applicable successor provisions. Where, in any specific case, different sections of the code specify different materials, methods of construction or other requirements, the most restrictive shall govern. Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall govern.

**Verification:** Within 30 days after receipt of the Certificate of Occupancy, the project owner shall submit to the CPM a statement of verification, signed by the responsible design engineer, attesting that all designs, construction, installation and inspection requirements of the applicable LORS and the Energy Commission's Decision have been met in the area of facility design. The project owner shall provide the CPM a copy of the Certificate of Occupancy within 30 days of receipt from the CBO [~~2001~~ *2007* CBC, Section ~~109~~ *110* – Certificate of Occupancy].

**GEN-5** Prior to the start of rough grading, the project owner shall assign at least one of each of the following California registered engineers to the project: A) a civil engineer; B) a soils engineer, or a geotechnical engineer or a civil engineer experienced and knowledgeable in the practice of soils engineering; and C) an engineering geologist. Prior to the start of construction, the project owner shall assign at least one of each of the following California registered engineers to the project: D) a design engineer, who is either a structural engineer or a civil engineer fully competent and proficient in the design of power plant structures and equipment supports; E) a mechanical engineer; and F) an electrical engineer. [California Business and Professions Code section 6704 et seq., and sections 6730, 6731 and 6736 require state registration to practice as a civil engineer or structural engineer in California.]

All transmission facilities (lines, switchyards, switching stations and substations) are handled in Conditions of Certification in the Transmission System Engineering section of this document. *(Transmission lines are not included in the Amendment Petition.)*

The tasks performed by the civil, mechanical, electrical or design engineers may be divided between two or more engineers, as long as each engineer is responsible for a particular segment of the project (e.g., proposed earthwork, civil structures, power plant structures, equipment support). No segment of the project shall have more than one responsible engineer. The transmission line may be the responsibility of a separate California registered electrical engineer.

The project owner shall submit to the CBO for review and approval, the names, qualifications and registration numbers of all responsible engineers assigned to the project [~~2001~~ *2007* CBC, Section 104, Powers and Duties of Building Official].

If any one of the designated responsible engineers is subsequently reassigned or replaced, the project owner shall submit the name, qualifications and registration number of the newly assigned responsible engineer to the CBO for review and approval. The project owner shall notify the CPM of the CBO's approval of the new engineer.

A. The civil engineer shall:

1. Review the Foundation Investigations Report, Geotechnical Report or Soils Report prepared by the soils engineer, the geotechnical engineer, or by a civil engineer experienced and knowledgeable in the practice of soils engineering

2. Design, or be responsible for design, stamp, and sign all plans, calculations and specifications for proposed site work, civil works and related facilities requiring design review and inspection by the CBO. At a minimum, these include: grading, site preparation, excavation, compaction, construction of secondary containment, foundations, erosion and sedimentation control structures, drainage facilities, underground utilities, culverts, site access roads and sanitary sewer systems; and

3. Provide consultation to the RE during the construction phase of the project and recommend changes in the design of the civil works facilities and changes in the construction procedures *as may be appropriate*.

B. The soils engineer, geotechnical engineer, or civil engineer experienced and knowledgeable in the practice of soils engineering, shall:

1. Review all the engineering geology reports

2. Prepare the Foundation Investigations Report, Geotechnical Report or Soils Report containing field exploration reports, laboratory tests and engineering analysis detailing the nature and extent of the soils that may be susceptible to liquefaction, rapid settlement or collapse when saturated under load [~~2001~~ *2007* CBC, ~~Appendix Chapter 33, Section 3309.5~~ *Chapter 18, Section 1802.6,* Soils Engineering Report; ~~Section 3309.6~~ *Chapter 18, Section 1802.7*, Engineering Geology Report; and Chapter 18, Section ~~1804~~ *1802*, Foundation and Soils Investigations];

3. Be present, as required, during site grading and earthwork to provide consultation and monitor compliance with the requirements set forth in the ~~2001~~ *2007* CBC, Appendix ~~Chapter 33; Section 3317~~ *J Section 105*, Grading Inspections; (depending on the site conditions, this may be the responsibility of either the soils engineer or engineering geologist or both); and

4. Recommend field changes to the civil engineer and RE. This engineer shall be authorized to halt earthwork and to require changes if site conditions are unsafe or do not conform with predicted conditions used as a basis for design of earthwork or foundations [~~2001~~ *2007* CBC, Section _____, Stop orders].

C. The engineering geologist shall:

1. Review all the engineering geology reports and prepare final soils grading report; and

2. Be present, as required, during site grading and earthwork to provide consultation and monitor compliance with the requirements set forth in the ~~2001~~ *2007* CBC, Appendix Chapter 33; Section 3317, Grading Inspections; (depending on the site conditions, this may be the responsibility of either the soils engineer or engineering geologist or both).

D. The design engineer shall:

1. Be directly responsible for the design of the proposed structures and equipment supports;

2. Provide consultation to the RE during design and construction of the project;

3. Monitor construction progress to ensure compliance with engineering LORS;

4. Evaluate and recommend necessary changes in design; and

5. Prepare and sign all major building plans, specifications and calculations.

E. The mechanical engineer shall be responsible for, and sign and stamp a statement with, each mechanical submittal to the CBO, stating that the proposed final design plans, specifications, and calculations conform with all of the mechanical engineering design requirements set forth in the Energy Commission's Decision.

F. The electrical engineer shall:

1. Be responsible for the electrical design of the project; and

2. Sign and stamp electrical design drawings, plans, specifications, and calculations.

**Verification**: At least 30 days (or project owner and CBO-approved alternative timeframe) prior to the start of rough grading, the project owner shall submit to the CBO for review and approval, resumes and registration numbers of the responsible civil engineer, soils (geotechnical) engineer and engineering geologist assigned to the project.

At least 30 days (or project owner and CBO approved alternative timeframe) prior to the start of construction, the project owner shall submit to the CBO for review and approval, resumes and registration numbers of the responsible design engineer, mechanical engineer and electrical engineer assigned to the project.

The project owner shall notify the CPM of the CBO's approvals of the responsible engineers within five days of the approval.

If the designated responsible engineer is subsequently reassigned or replaced, the project owner has five days in which to submit the resume and registration number of the newly assigned engineer to the CBO for review and approval. The project owner shall notify the CPM of the CBO's approval of the new engineer within five days of the approval.

**CIVIL-1** The project owner shall submit to the CBO for review and approval the following:

1. Design of the proposed drainage structures and the grading plan;
2. An erosion and sedimentation control plan;
3. Related calculations and specifications, signed and stamped by the responsible civil engineer; and
4. Soils Report, Geotechnical Report or Foundation Investigations Report required by the ~~2001~~ *2007* CBC [~~Appendix Chapter 33, Section 3309.5~~ *Chapter 18, Section 1802.6 and 1802.8* Soils Engineering Report; ~~Section 3309.6~~ *Chapter 18, Section 1802.7* Engineering Geology Report; and Chapter 18, Section ~~1804~~ *1802* Foundation Investigations].

**Verification**: At least 15 days (or project owner and CBO approved alternative timeframe) prior to the start of site grading the project owner shall submit the documents described above to the CBO for design review and approval. In the next Monthly Compliance Report following the CBO's approval, the project owner shall submit a written statement certifying that the documents have been approved by the CBO

## 5.5.7 References

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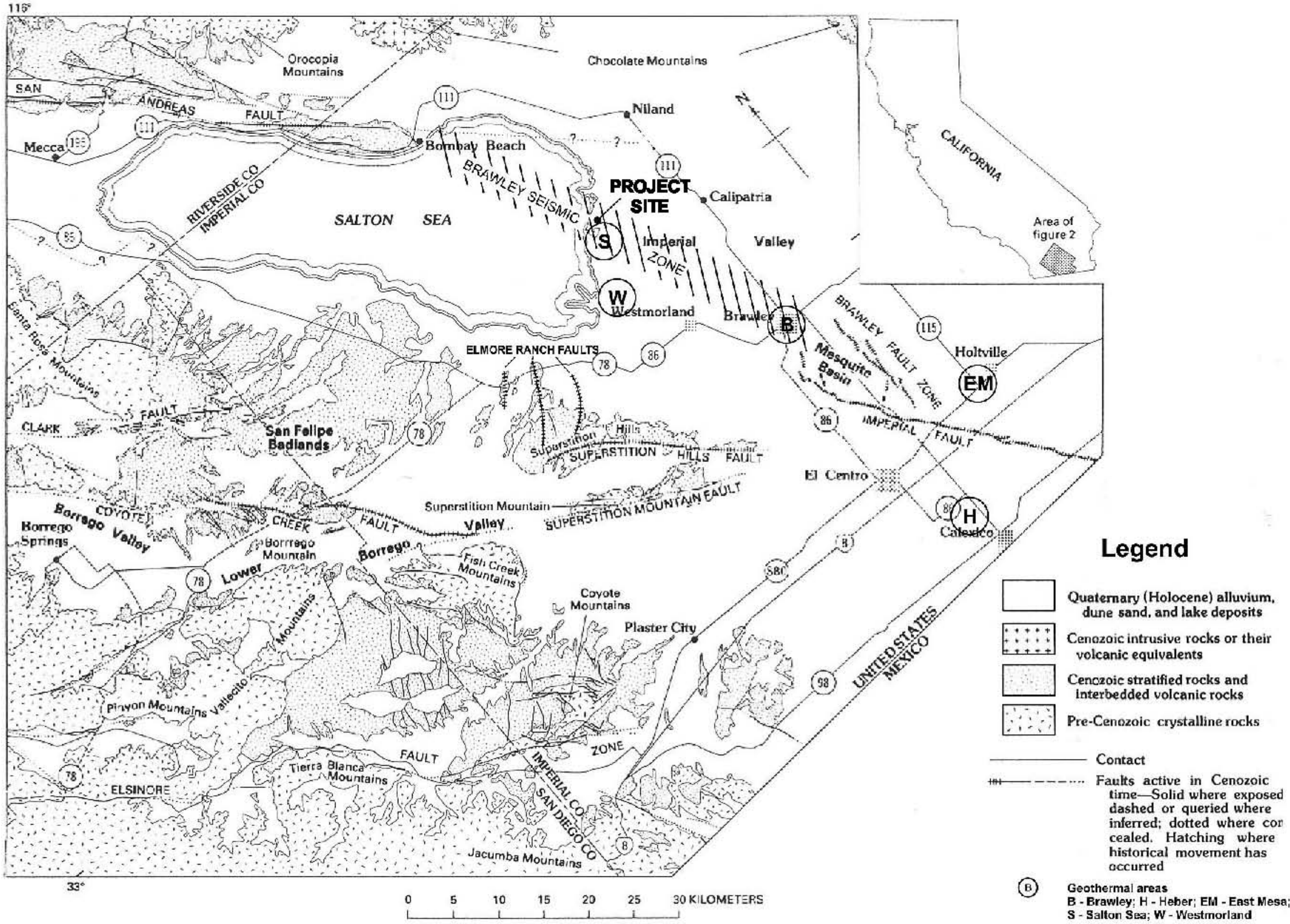


Data Source: URS, 2002

**Amended SSU6 Project**

**Figure 5.5-1**
**Regional Geology**

CE GENERATION LLC
A MIDAMERICAN ENERGY HOLDINGS COMPANY AFFILIATE

AECOM

Project: 12676-001
Date: February 2009

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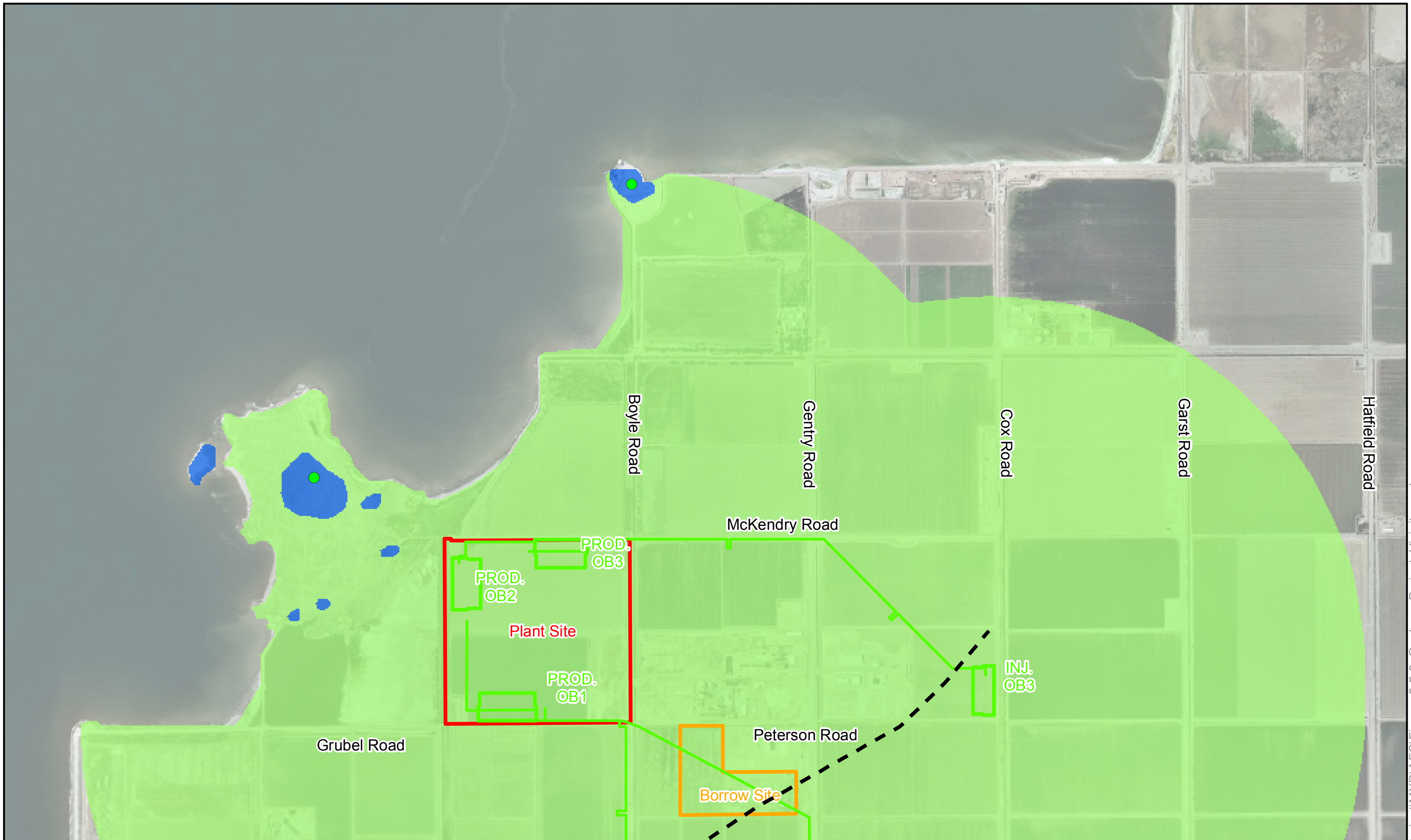


See Mapsheet 2 of 2

**Legend**

Plant Site
Borrow Site
Proposed Well Pad
Proposed Pipeline
Lake Deposits
Recent Volcanics (Rhyolite)
Mineral Resources Burrow Site (Pumice)
Projected Trace of Deep (-2000 ft) Main Blind Faults within Geothermal Reservoir

1 inch = 2,000 feet

0 1,000 2,000 4,000 Feet

N W E S

**Amended SSU6 Project**

**Figure 5.5-2**
**Geologic Map of Project Vicinity**

Mapsheet 1 of 2

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AECOM

Project: 12676-001
Date: February 2009

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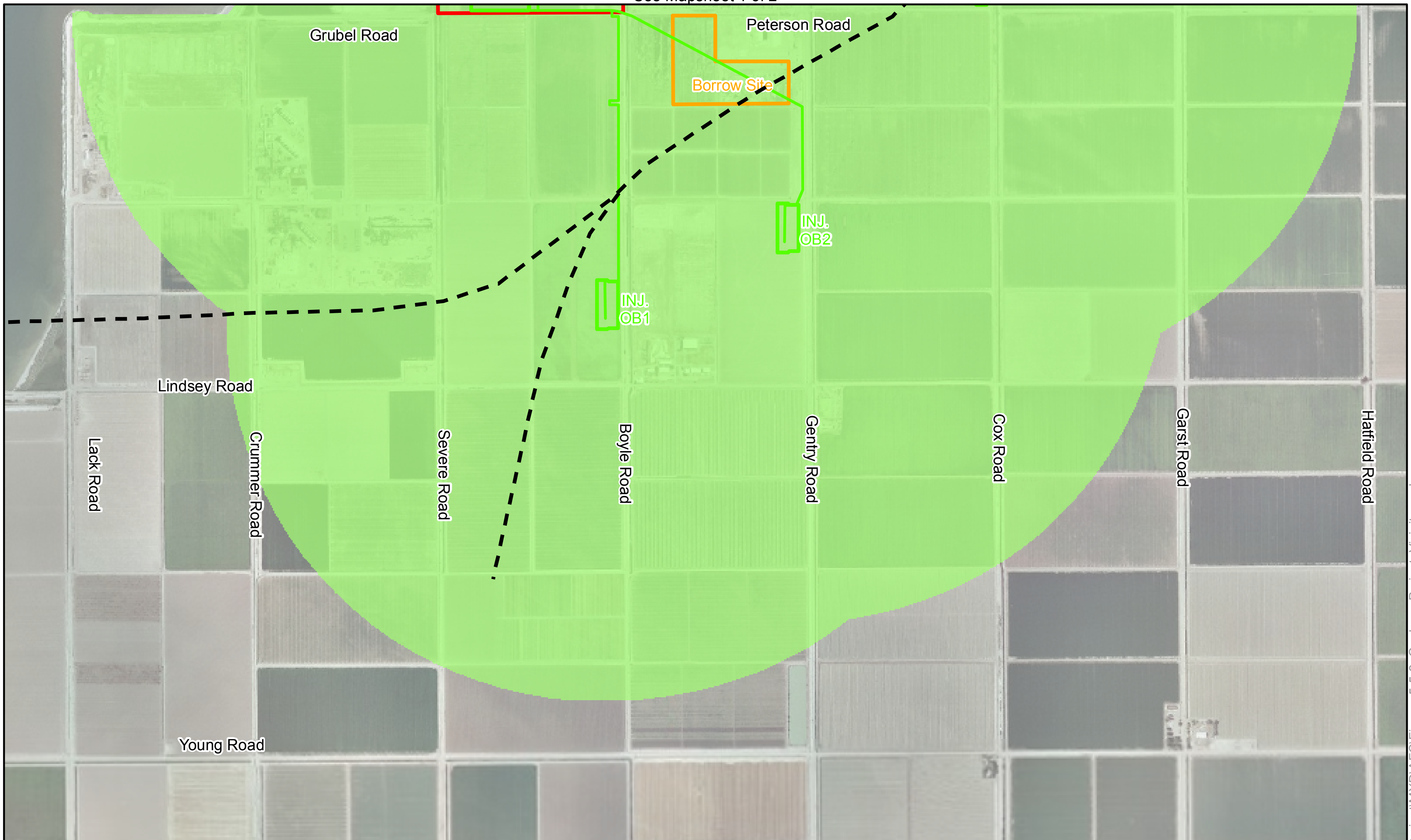
See Mapsheet 1 of 2




**Legend**

- Plant Site
- Borrow Site
- Proposed Well Pad
- Proposed Pipeline
- Lake Deposits
- Recent Volcanics (Rhyolite)
- Mineral Resources Burrow Site (Pumice)
- Projected Trace of Deep (-2000 ft) Main Blind Faults within Geothermal Reservoir

1 inch = 2,000 feet

0 1,000 2,000 4,000 Feet

N W E S

**Amended SSU6 Project**

**Figure 5.5-2**
**Geologic Map of Project Vicinity**

Mapsheet 2 of 2

CE GENERATION LLC
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AECOM

Project: 12676-001
Date: February 2009

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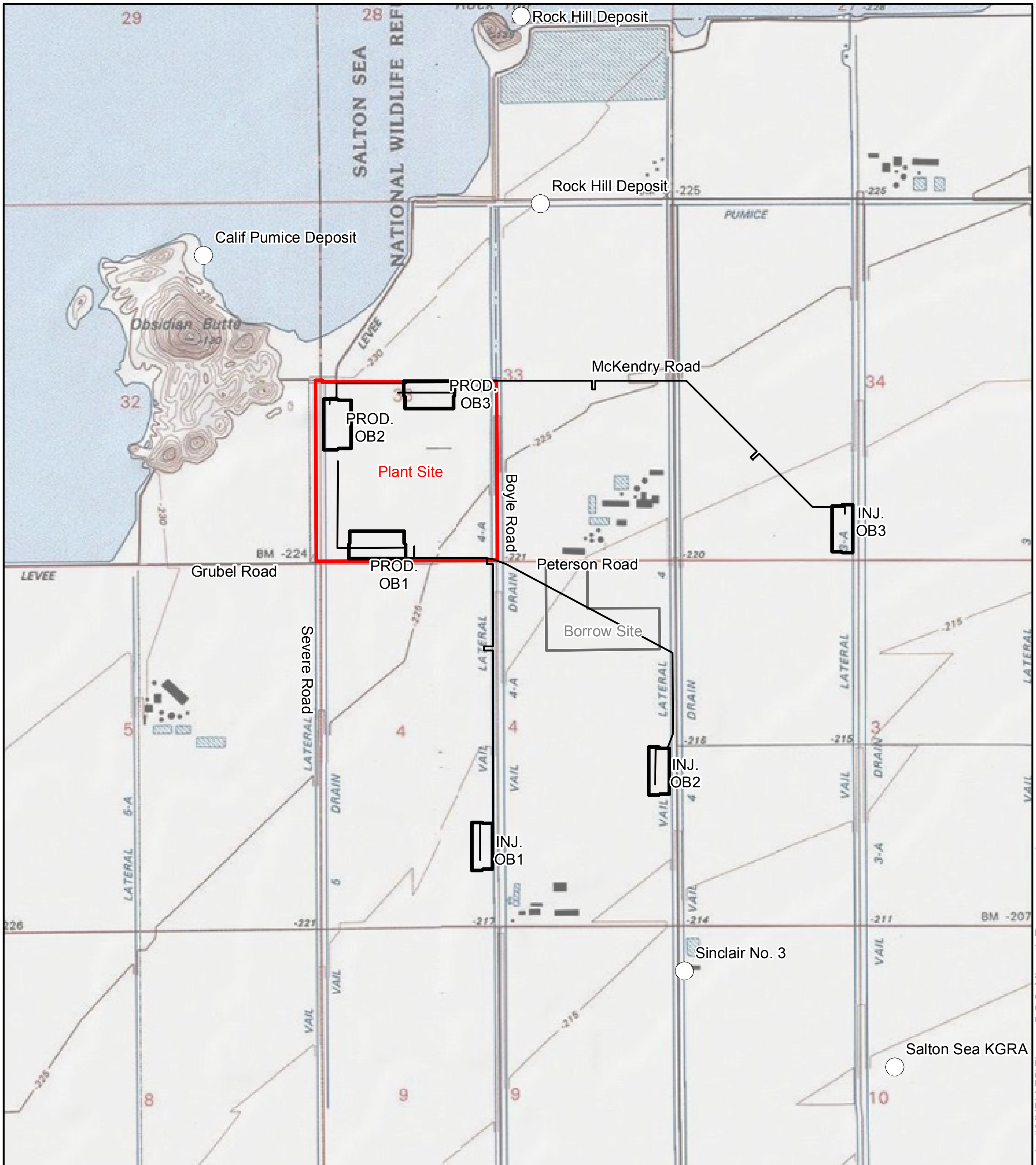


**Legend**

Plant Site

Proposed Well Pad

Borrow Site

Proposed Pipeline

Mineral Resource Locations

N W E S

1 inch = 2,000 feet

0 1,000 2,000 4,000 Feet

**Amended SSU6 Project**
**Figure 5.5-3**
**Mineral Resources**

Data Source: Geotechnics, 2002,
as presented in URS, 2002

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AECOM

Project: 12676-001
Date: February 2009

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